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TITLE: HIGH-SPEED IMAGING OF BLOOD SPLATTER PATTERNS

AUTHOR(S): Thomas E. McDonald, Kevin A. Albright, Nicholas S. P. King, and George J. Yates

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Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

High-Speed Imaging of Blood Splatter Patterns

Thomas E. McDonald, Kevin A. Albright,
Nicholas S. P. King, and George J. Yates

Los Alamos National Laboratory
Department of Energy

and

George F. Levine

Bureau of Forensic Services
Office of Attorney General, State of California

ABSTRACT

The interpretation of blood splatter patterns is an important element in reconstructing the events and circumstances of an accident or crime scene. Unfortunately, the interpretation of patterns and stains formed by blood droplets is not necessarily intuitive and study and analysis are required to arrive at a correct conclusion. A very useful tool in the study of blood splatter patterns is high-speed photography. Scientists at the Los Alamos National Laboratory, Department of Energy (DOE), and Bureau of Forensic Services, State of California, have assembled a high-speed imaging system designed to image blood splatter patterns. The camera employs technology developed by Los Alamos for the underground nuclear testing program and has also been used in a military mine detection program. The camera uses a solid-state CCD sensor operating at approximately 650 frames per second (75 MPixels per second) with a microchannel plate image intensifier that can provide shuttering as short as 5 ns. The images are captured with a laboratory high-speed digitizer and transferred to an IBM compatible PC for display and hard copy output for analysis. The imaging system is described in this paper.

INTRODUCTION

The interpretation of blood splatter patterns is an important element that is used by forensic scientists in deducing events at a crime scene. However, the shape of liquid drops and the formation of splatter patterns often do not follow intuition; this is especially true in the case of blood (Refs. 1 and 2). Patterns formed by blood droplets can be counterintuitive and detailed study is required to avoid erroneous interpretations of such patterns (Refs. 3 and 4). Employing imaging technology developed for the underground nuclear testing program, a high-speed electronic imaging system using a solid-state electronic camera has been assembled by scientists at the Los Alamos National Laboratory, Department of Energy, and at the Bureau of Forensic Services, State of California. The imaging system is being used for recording images of the formation of blood splatter patterns that can be used by forensic scientists in the interpretation of such patterns. The image can also be used for illustrating and explaining the formation and interpretation of blood splatter patterns during trial proceedings.

IMAGING SYSTEM

A block diagram of the imaging system is shown in Figure 1. The system consists of a high-speed electronic CCD camera with intensifier, a high-speed frame grabbing subsystem, and the drop release mechanism with impact area. The drop release mechanism is an adaptation of a mouse trap and dropper to propel drops horizontally and strike appropriate targets. The volume of the drop is controlled by the amount of liquid loaded into the dropper. The spring-loaded arm can be set initially at various locations

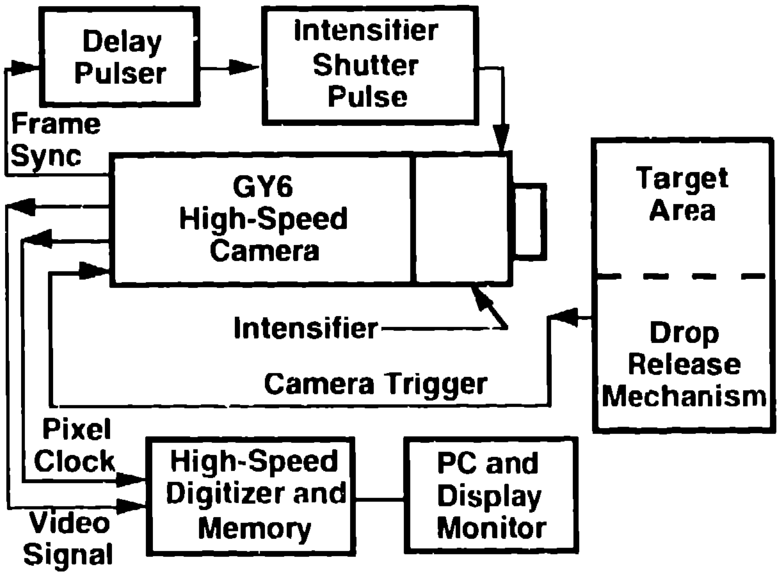

Fig 1. Block diagram of high-speed imaging system. The camera is triggered by the drop release mechanism and images at the rate of approximately 700 frames per second or 70 Mpixels per second.

along the path of travel and released. When released, the arm strikes the bulb of the dropper and propels the drop of liquid into the target area. An electrical contact on the mechanism provides a trigger pulse to the camera when the dropper bulb is struck and starts the operation of the camera at a rate of approximately 650 frames per second. The intensifier allows a shutter speed of as short as approximately 5 ns. The shutter speed is more than adequate to effectively eliminate smear in the image. A high-speed frame grabber consisting of a LeCroy digitizer and memory modules is used to capture and store the images. The image data are transferred to an IBM compatible PC where the image can be displayed on a monitor or where a hard copy can be obtained.

HIGH-SPEED CAMERA AND INTENSIFIER

The heart of the imaging system is the high speed camera and intensifier. The camera, designated the GY6, is an outgrowth of a similar camera developed by Los Alamos for the nuclear underground testing program. The camera uses a Loral Fairchild charge coupled device (CCD), designated the CCD222, which was designed for standard television applications. The pixel array size of a field from the imager is 244 × 380. Although the CCD222 was designed for standard television operation at pixel rates of approximately 8 MHz, we have found that the 222 can be operated at pixel readout rates as high as approximately 75 MHz, which gives a frame rate of over 650 frames per second. The GY6 has been designed to operate in either the standard television video RS-170 mode or at the higher clock rates. A photograph of a GY camera and intensifier is shown in Figure 2.

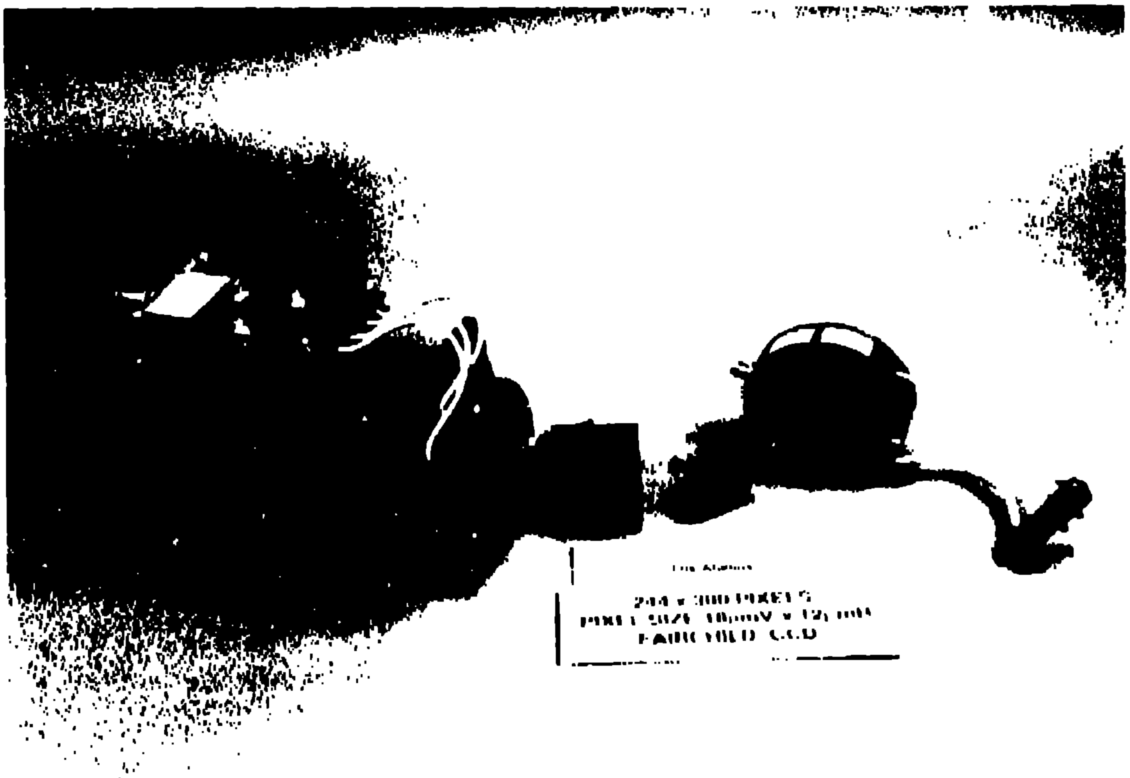

Fig 2. Photograph of GY series camera used in the high-speed imaging system. This camera series was designed for the nuclear underground testing program and has also been employed in a military mine detection project.

FRAME GRABBER

Commercial frame grabber subsystems that can operate at the GY6 pixel rates of 75 Mpixels per second are not available. Therefore, we have employed a high speed laboratory digitizer and memory units to capture the image data from the GY6 and interface to an IBM compatible PC for display and hard copy output. The digitizer is a LeCroy model TR8818 transient recorder, and the modules are four LeCroy MM8103A memory modules in a CAMAC configuration. The transient recorder and memory modules are standard CAMAC modules. A DSP Technology Model 6002 is a combined CAMAC Crate controller and Dataway Display Module that is used to transfer the data to the PC. A Univision Technologies, Inc. UDC 2600 Display Controller accepts the data and displays it on the PC monitor. The LeCroy transient recorder and memory modules can operate up to 100 Msamples per second. To achieve synchronous operation of the camera and recorder, the clock signal from the GY6 camera is used as the master timebase for the recorder and memory. The PC used in the system is a Compaq Portable 386/20. The frames captured by the frame grabber can be reformatted into a standard television format, such as RS-170, for playback on a VCR tape recorder, if desired.

DROP RELEASE MECHANISM

A diagram of the drop release mechanism is shown in Figure 3. The mechanism, which is a simple adaptation of a mouse trap, consists of a spring-loaded arm that impacts the rubber bulb of a dropper and propels a drop of blood onto a target. The

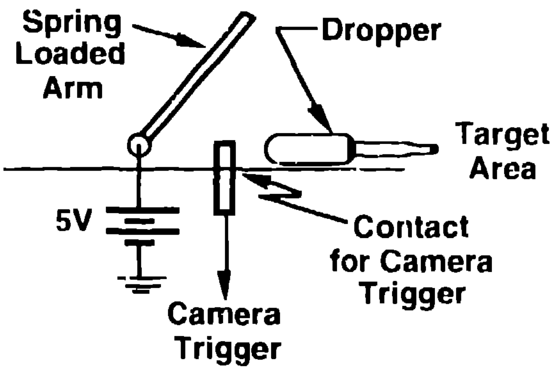

Fig 3. Sketch of drop release mechanism showing spring-loaded arm, position of dropper, and contact for providing a trigger pulse to the camera. When the arm strikes the dropper bulb, the drop of liquid in the dropper tube is expelled into the target area where it can be imaged as it strikes a target.

volume of the drop is determined at the initial loading of the dropper and the velocity is determined by the force of the arm striking the rubber bulb, which is controlled by the distance the arm is pulled back against the force of the spring. A metal contact is installed near the end of travel of the arm that provides a trigger to the camera when the metal arm touches the contact and closes an electrical circuit.

DESCRIPTION OF OPERATION

The operation of the system begins when, having loaded the dropper with the desired volume of blood, the spring-loaded arm is pulled back the appropriate distance to achieve the desired velocity of the drop and released. The arm strikes the bulb of the dropper and propels the drop into the target area. At the same time the arm touches the electrical contact that triggers operation of the camera. The camera supplies a frame sync pulse to the intensifier shutter pulser through a timing delay. The timing delay is adjusted such that the shutter pulse, which can range from 5 ns to microseconds, occurs during the first of the camera frame readout. The frame readout requires approximately 1.5 ms. A frame readout consists first of transferring the charge from all pixel sites in the CCD into vertical interline registers that are located adjacent to the pixel sites on the CCD. The changes are then transferred to a horizontal register where they are sequentially clocked out of the CCD at the pixel clock rate of 75 Mpixels per second through the camera electronics. The individual pixel signals are converted to an analog signal for each line of the video image. This analog signal is converted to digital form by the high speed LeCroy digitizer and stored in the memory modules from which the image data can be transferred to the PC for display and hardcopy output.

When the charge in the pixel sites is transferred to the interline registers the pixel sites are ready to integrate the light from the image for the next frame of data. Thus, the shutter pulse to the intensifier is timed to arrive at the first of a frame transfer to allow the image to form on the intensifier output phosphor and then to decay away before the next frame transfer occurs. The light output of the intensifier phosphor decays to almost zero within a few tens of microseconds; however, a long tail of low-level light can last up to a millisecond. It is, therefore, important for the shutter to occur at the beginning of the frame transfer to allow the image on the intensifier of one frame to decay as much as possible before the next frame is taken.

To study splatter formation, it is necessary to take a number of images of a single drop during its flight and the number of images that can be taken depends upon the drop velocity. Table 1 gives the distance between images of a drop and the number of images of a drop in a 10-cm distance at various velocities. Good time resolution is achieved up to velocities of 4 to 5 meters per second, and the time resolution appears to be adequate up to velocities as high as 14 to 15 meters per second if details of the breakup of the drop during impact are not required.

Table 1

Indication of Time Resolution at Various Drop Velocities for a 650 Frame per Second Rate

Velocity (m/s)	Distance Between Frames (mm)	Number Images In 10 cm
1	1.5	65
2	3.1	32
4	6.1	16
6	9.2	11
9	13.8	7
12	18.4	5
15	23.1	4

INCREASING SYSTEM FRAME RATE

A potential improvement in the imaging system is increasing the frame rate to achieve increased time resolution. The frame rate of the present GY6 is limited by the clocking limitations of the CCD sensor. The electronics in the GY6 camera system can support a clock rate of 100 MHz; however, the CCD222 cannot operate at the 100 MHz rate. It appears that the limitation of the CCD222 is the bandwidth of the output amplifier located on the chip. With relatively little design modification to increase the bandwidth of the output amplifier, the CCD222 could be operated at the 100 MHz pixel rate. This would allow a frame rate of just over 1000 frames per seconds. Still higher frame rates can be achieved through sequential operation of multiple imagers. For example, a four camera imaging system with each camera operating at 1000 frames per second can be configured to achieve a frame rate of 4000 frames per second.

CONCLUSIONS

A high-speed imaging system has been assembled that can be used to image the formation of blood splatter patterns. The system is based on technology developed for the underground nuclear testing program. The present system can operate at frame rates of 650 frames per second and improvements have been identified that will achieve frame rates of 1000 frames per second and higher. These improvements will be implemented as technology advances are made and resources become available.

REFERENCES

1. James E. McDonald, "The Shape of Raindrops," Scientific American, February 1954.

2. Peter A. Pizzola, Steven Roth, and Peter R. De Forest, "Blood Droplet Dynamics-I", Journal of Forensic Sciences, JFSCA, Vol. 31, No. 1, January 1986.

3. Peter A. Pizzola, Steven Roth, and Peter R. De Forest, "Blood Droplet Dynamics-II", Journal of Forensic Sciences, JFSCA, Vol. 31, No. 1, January 1986.

4. H. L. MacDonell and C. G. Panchou, "Blood Stain Patterns on Human Skin," Journal of Canadian Society of Forensic Science, Vol. 12, No. 3, September 1979.